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(54) **Twin axis colour balance control**

(57) Twin Axis Colour Balance Control reduces the number of active controls to two and replaces the need to name the colour error with an easier warm/cold concept that is visually seen to be simply right or wrong. The primary control follows the Planckian locus to correct colour temperature lighting errors in a cold/warm direction in the colour diagram. A secondary control follows a green/magenta direction to trim out colour casts from other non-Planckian errors. Since a colour diagram is two dimensional it can be navigated with only two controls, thus simplifying the process of colour correction. The combined use of both controls will move the white point to anywhere off the Planckian locus to accommodate all other colour balance inaccuracies due to film and/or signal processing errors. The Planckian locus can be tracked or closely followed with electronic circuits controlled by a computer programme. One method would be to use a look up table (LUT) based upon the equivalent Mired values of colour temperature, automatically adjusting the relative proportions of Red, Green and Blue while the operator concentrates on visually assessing their effect on the picture in cold/warm terms and the all important - does it look right? A mathematical function can also be derived to follow the Planckian locus.

Figure 1

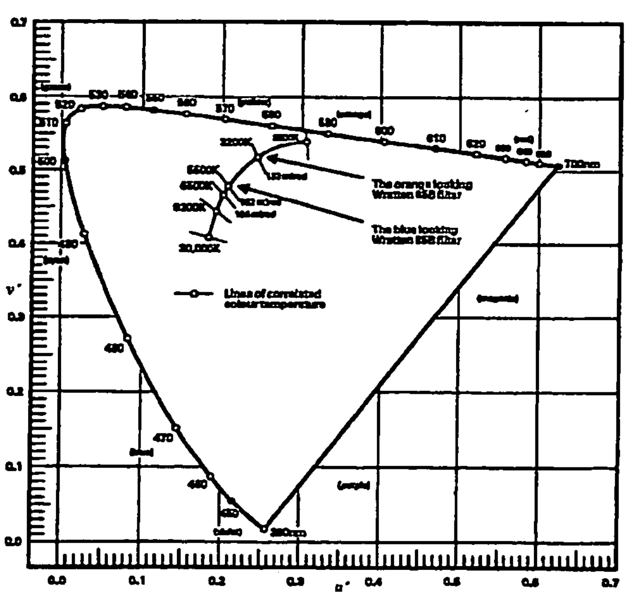

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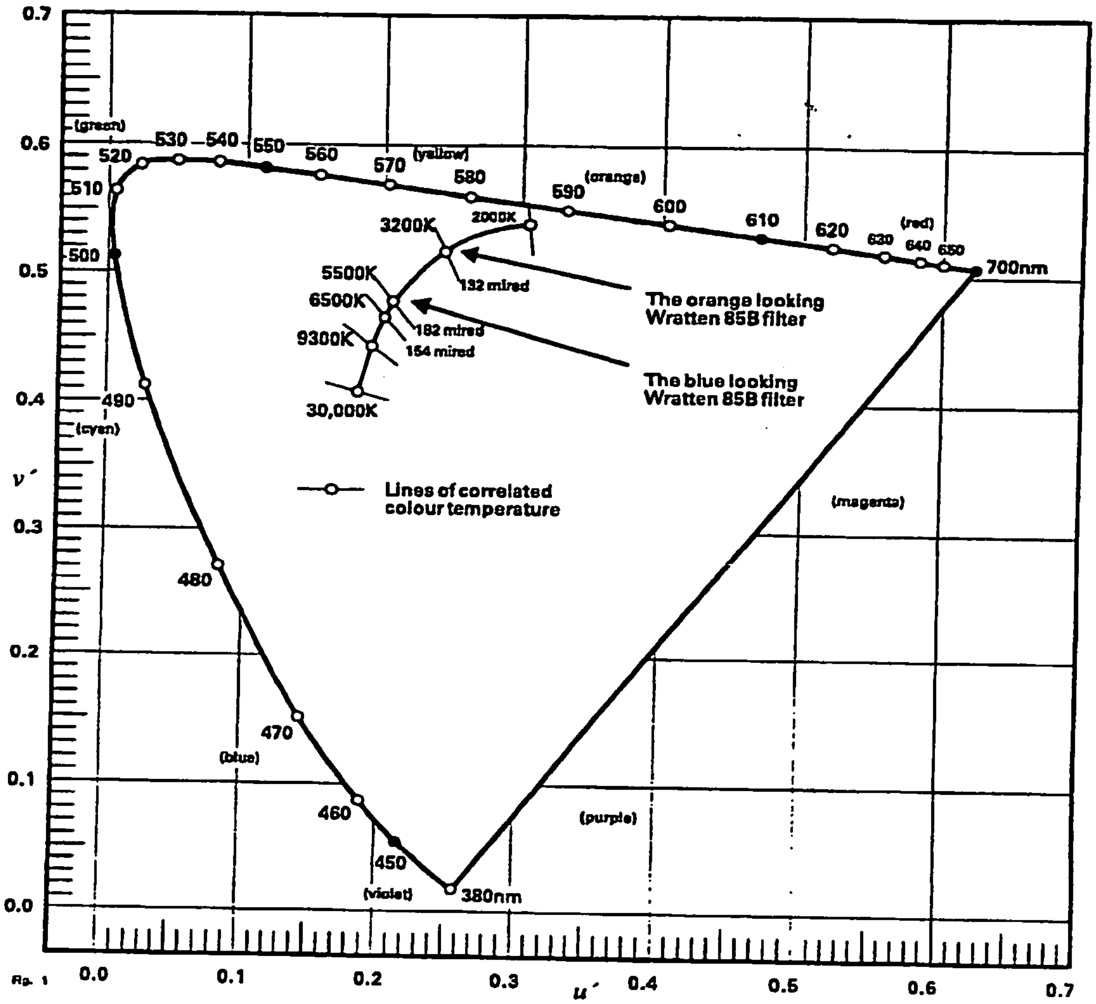
Figure 1



(green)
520
530
540
550
560
570
(yellow)
580
590
(orange)
600
610
620
630
640
650
(red)
700nm
510
500
490
(cyan)
480
470
(blue)
460
450
(violet)
380nm
(purple)
(magenta)
3200K
2000K
5500K
6500K
9300K
30,000K
132 mired
182 mired
154 mired
The orange looking Wratten 85B filter
The blue looking Wratten 85B filter
Lines of correlated colour temperature
v´
u´
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Fig. 1

Figure 2

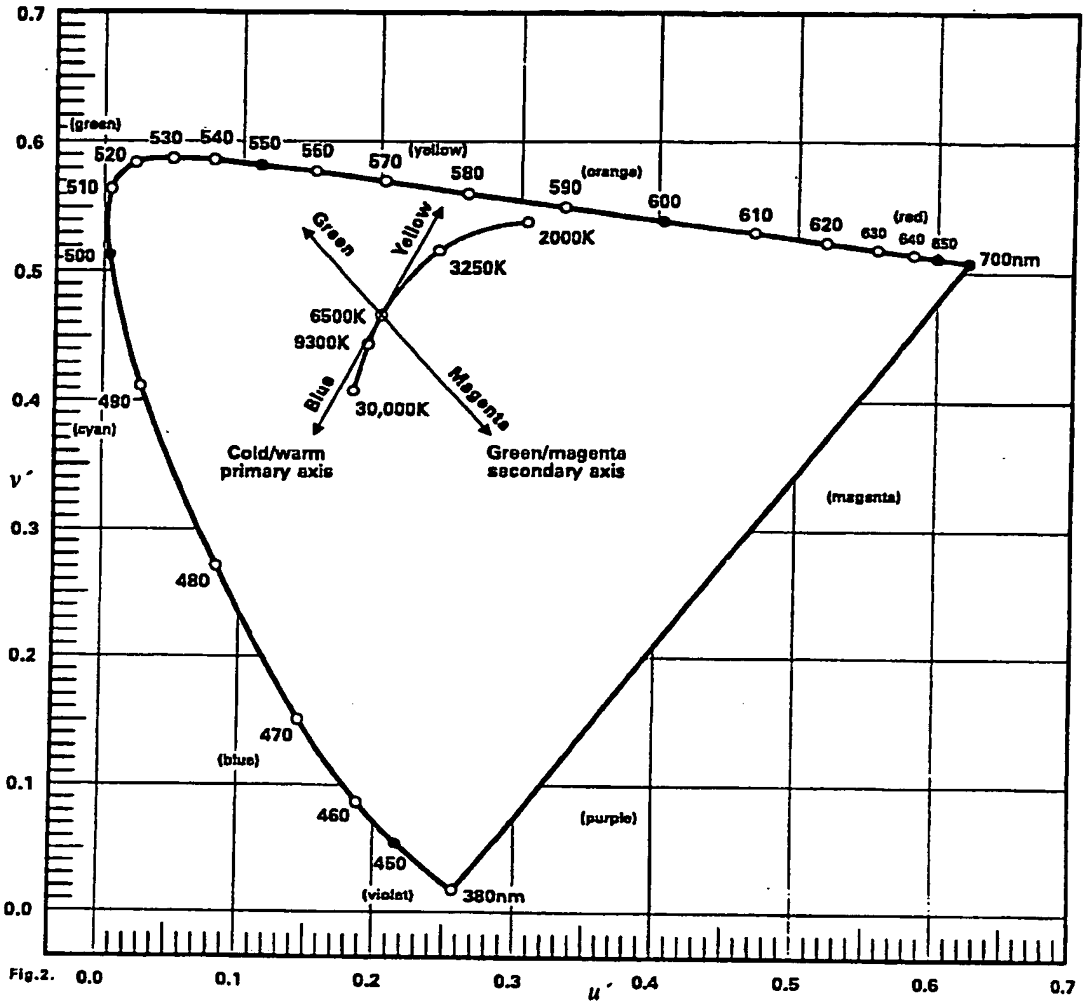


Fig.2.

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Figure 3

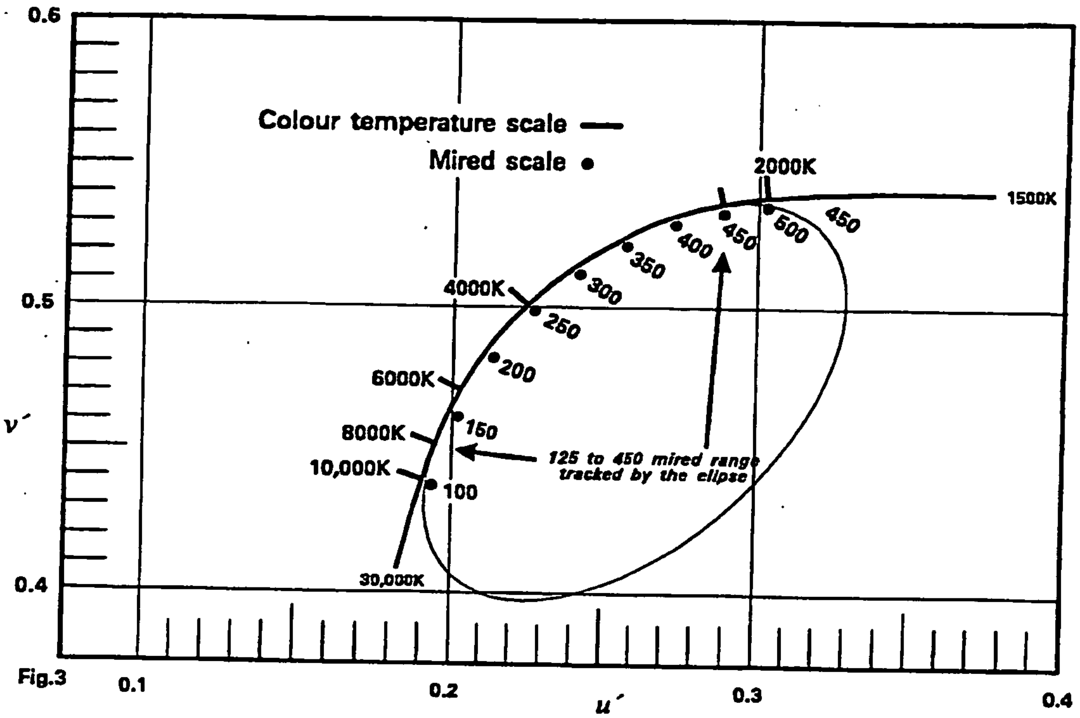

Fig.3

2. INTRODUCTION

The current general procedure for adjusting colour balance is to operate three primary colour controls. This dates back to early colour film practice when Yellow, Cyan and Magenta optical filters would be mechanically added to, or removed from, the printer light path. With the introduction of colour television the number of controls remained the same but became Red, Green and Blue, operating on the three electronic signals. At about the same time the three RGB controls were combined in a number of mechanical ways and presented to an operator in the form of a single joystick control that could be pushed to go in any direction, to represent any hue in the colour diagram. The freedom to cover the whole gamut of colours on one control now left the operator to decide, by colour name, where to move the joystick, which is not an easy task to perform, especially in a hurry. This form of control has continued into some DTP (desk top publishing) and pre-press applications where a small colour diagram is displayed on a screen in order to allow an operator to navigate a point in the colour diagram with similar joystick freedom, but this time using a mouse or the keyboard arrow keys

3. THE COLOUR DIAGRAM

Any colour can be fully described by three attributes as, Hue, Brightness and Saturation (other names are also sometimes used). It follows that any graphical representation of all three attributes will need to be a three dimensional drawing, hence the term 'colour solid' or 'colour space'. The CIE (Commission Internationale de l'Eclarage) studied the problems of colour measurement and specification in 1931 and proposed an XYZ colour space in which all colours could be represented. The colour diagram associated with this colour space was called the 1931 $x\,y$ Chromaticity Diagram and can represent all values of Hue and Saturation. The other dimension, brightness, is not directly included and has to be specified separately. The same basic data still applies today, but improvements have been made in their representation to make distances anywhere in the colour diagram more closely correspond to perceived colour differences. The most recent colour diagram claiming to have 'more uniform colour spacing' is called the 1976 CIE $u'\,v'$ Chromaticity Diagram and this diagram is used to illustrate this paper. The term 'chromaticity diagram' is strictly correct but 'colour diagram' is often used and is probably more widely understood.

A colour diagram is like a land map with any position or place being designated by numbers and letters along two edges of the map. A road map of London might place Hyde Park at reference H5. Similarly a colour in our colour diagram can be pin pointed with two co-ordinates, u' and v'. Fig.1 shows the 'daylight' colour of 6500K represented at $u' = 0{\cdot}1978$ and $v' = 0{\cdot}4613$. The chromaticity of several other colour temperatures are also marked.

4. GAMUT OF COLOURS

If we plot the chromaticities of a set of three primary colours on a colour diagram, then join them with straight lines, we will see a triangle that outlines all the colour mixtures possible with those primary colours. This area contains all the colours possible from mixing those particular primaries and is referred to as a colour gamut or gamut of colours associated with those primaries. Fig.1 shows the Red, Green and Blue television primary colours. This triangle defines the range or gamut of colours possible from using these primaries. Colours outside this triangle, or gamut, cannot be reproduced with these primaries. Other primary colours, say printers inks, will form different colour gamuts to the one illustrated here.

5. COLOUR BALANCE

The quality of colour balance is usually assessed by looking at a picture. When pictures look good it can be safely assumed that a number of technical conditions have been met apart from aesthetic ones. We might say that the colour of the illumination matched the set-up of the camera, or a more objective appraisal might arise from observing that zero sub-carrier was transmitted from grey elements in television pictures, that a piece of colour print film depicting a grey had equal Red, Green and Blue densities. The adjustment of the colour balance of a colour system, first to set it up and/or second, to correct a colour error is generally made by adjusting one or more of three controls. These three controls operate on the primary colours associated with whatever system is in use, being either the additive Red, Green and Blue colours or, the subtractive Yellow, Cyan and Magenta colours. The effective task is 'to think about six primary colours' since each set of system primaries has a corresponding set of complimentary colours. For example, advancing the Red control makes the picture more Red while operating the same Red control the other way will give the picture a Cyan hue. The result of adjusting these system primaries is to alter what we call the white point. These adjustments are made with amplifier gain in the case of electronic circuits and colour filters in the case of cameras and optical printing. The same order of c lour correction can be applied to selected parts of the tone scale, for example in the shadows only, the highlights nly, or just the mid tones.

6. THE WHITE POINT

The white point of a system is where neutral greys (which includes light greys and white as well as dark greys and black) are reproduced on the colour diagram. The exact point depends on the design and adjustment of the system in question. It is important that the colour of illumination matches the colour of a cameras white point. Typical white points, for example, are 3200K for tungsten balanced film, 5500K for daylight film, D_{65} for TV monitors. When electronic controls, or colour filters are available, then the matching of illuminant and system white points can be exact, so avoiding any colour cast. If the colour temperature of these two white points do not match then the picture is likely to have a colour cast. Removal of that colour cast is then easy by using the primary axis as outlined here.

7. DETERMINING THE COLOUR ERROR IS DIFFICULT

It is difficult to quickly and precisely identify an unwanted colour error present in a picture, give it a colour name, and to then nominate one or more of the primary colours for adjustment that will then cancel out the unwanted colour error. Much trial-and-error or hit-and-miss goes into time consuming joystick or mouse navigation around the colour diagram with more colours being presented, and then rejected, than the one required to correct the image at hand. In fact, pictures are often left 'un-corrected' and are seen looking too blue, too orange or greenish. These colours can be attributed to un-corrected colour temperature errors and to uncorrected fluorescent lighting.

8. REQUIREMENTS FOR GOOD COLOUR

All colour systems are capable of originating good colour if they have matched curves, and the white point of the system and illumination are matched. Matched curves means that the individual colour transfer characteristic curves, or tone scales, match each other in shape. It is then necessary to preserve that overall balance through subsequent stages of film or signal processing, and programme editing. Good colour matching between images may require small colour balance changes to some of them so that a series of assembled images have a similar look, in a picture matching sense, when seen in quick sequence.

The following illustration of colour balance and colour temperature uses colour film as an example. The principles outlined are not exclusive to film but are true for all colour imaging devices.

9. COLOUR TEMPERATURE AND THE WHITE POINT

If a solid body is heated up it will at first glow red, then orange, yellow, 'white' and maybe reach a blue colour before melting. The colour of these objects is directly related to their temperature on the Kelvin scale, which is equivalent to degrees Celsius + 273·15. The metal tungsten used in tungsten filament lamps can be heated up to 3400K before melting. A 3200K lamp will look warmer than the 3400K sample. Note that we are now using the colour temperature scale as a measure of colour with warm colours at one end and cooler colours at the other.

Colour film is available in two basic types, one balanced for use in daylight and the other for use in artificial light. Daylight film has a white point balanced for a colour temperature of 5500K and artificial light film has a white point balanced to tungsten light with a colour temperature of 3200K or 3400K. The camera operator who finds the wrong film in the camera (or the wrong lighting illuminating the scene) turns to one of the two most used colour filters to convert the light entering the lens to match the film in the camera. The orange looking Wratten 85B (D to A, daylight to artificial light filter) is used to convert daylight scenes to tungsten film, and the blue looking Wratten 80B (A to D, artificial light to daylight filter) is used to convert tungsten lit scenes for daylight film. Television cameras follow these film practices, sometimes automatically.

10. The Kodak Wratten range of colour filters is extensive. Other manufacturers make similar products.

11. THE PLANCKIAN LOCUS

If a range of colour temperatures are plotted on a colour diagram the unique curved line so produced is called the Planckian locus. This locus is unique to colours obtained from heated bodies or more correctly from 'black body radiators'. Fig.1 shows the 1976 CIE *u' v'* chromaticity diagram with the Planckian locus plotted on it. The two light correction filters, Wratten 85B and 80B, operate very precisely by converting, or shifting, the colour of light from one position on the Planckian locus to that at another position. Many other colour filters are available to make small and large colour shifts.

Since the colour of all phases of daylight fall on or near to this unique line, the Planckian locus, it therefore represents all likely errors of colour balance due to colour temperature errors and consequently offers a simple formulae for their correction.

Colours that fall near to but not on the Planckian locus are strictly speaking not black body radiators and are given 'correlated colour temperature' values. A good example would be a fluorescent lamp that uses an exited gas rather than a solid body to create part of its light emission. Lines of correlated colour temperatures are shown in Fig.1.

12. TYPICAL COLOUR TEMPERATURE VALUES

The colour temperature points marked in Fig.1 for illustration are: 2000K, the colour of red sunlight. 3200K, the colour of artificial tungsten light. 5500K, the colour that daylight film is balanced to. 6500K, the colour of 'average daylight', the white point of television and DTP pictures and the standard D_{65} fluorescent colour matching lighting. 9300K, the blue colour that some DTP and television screens can be set to, notably in the USA. 30,000K, is a very blue sky.

13. THE VARIATIONS OF DAYLIGHT

The colour of all phases of daylight and the white point of daylight and tungsten film all fall very close to, or on, the Planckian locus. From the sun with skylight obscured (a shaft of sunlight deep inside a shady area), to the open blue sky with the sun obscured (in a shady area, or facing the open blue sky with the sun behind), the two together on a fine sunny day (surfaces lit by sunlight and the blue sky), and their different mixtures through degrees of cloud cover (sunlight and skylight both illuminating 'the topside' of cloud cover while on our side we see the result of the two mixed together). Many colour filters are available to correct or 'shift' the light of any phase of daylight to any other, in large steps as previously described (Wratten 85B, 80B) or in small steps to slightly warm or cool an image. For instance the Wratten 81B will correct a television screen set at D_{65} to the 5500K of daylight type colour film.

14. ONE CONTROL TO TRACK THE PLANCKIAN LOCUS

If one control could be made to follow the line of the Planckian locus then the colour balancing of images shot in different phases of daylight would be much simplified. However there are other sources of colour error arising from the use of 'un-corrected' artificial lighting, light reflected from highly coloured nearby objects and random system errors. The cheaper types of gas discharge fluorescent lighting can produce a green/yellow colour cast due to the mercury gas discharge lines inside these tubes. Other errors can be due to: out of balance film stock, use of wrong colour filter on the camera (or none), colour contamination by light reflected from nearby coloured objects, out of balance film process and electronic circuits and etc.

15. Colour errors along the Planckian locus can be seen as warm/cold errors (remember the orange 85B blue, 80B filters), plus a possible colour cast from artificial lighting (the green/yellow cast from a fluorescent lamp) and other sources of error. These can all be corrected using just two controls operating crossed axis in the colour diagram. The primary control automatically follows the Planckian locus as the warm/cold axis without the overhead of colour naming or the many equivalent 'joystick' combinations of RGB or YCM. One other secondary control operates in the green/magenta direction to trim out all other errors. Their combined use can move the white point to anywhere in the colour diagram.

16 The colour temperature scale suffers from being an uneven scale of perceptual colour differences. This unevenness may be overcome by plotting micro-reciprocal-degrees (Mireds) instead of colour temperature values, as Fig.3 shows. The calibration of the primary control should therefore be in terms of, or close to, the visual intervals of the Mired scale.

KEY TO FIGURES 1, 2 and 3

Figure 1.
The black body locus plotted on the 1976 CIE *u'v'* chromaticity diagram. At the marked colour temperature points are lines of correlated colour temperature, which form the ideal direction for the *secondary axis* control.
Correlated colour temperatures from Color Science by Gunter Wyszecki and W.S.Stiles, 1967. Wiley.

The position of two Wratten filters are indicated, the orange looking 85B and the blue looking 80B.

Figure 2.
The 1976 CIE *u'v'* chromaticity diagram illustrating the two crossed axis. The *cold/warm primary axis* is also marked as *blue to yellow*. The *green/magenta secondary axis* is aligned with a correlated colour temperature of 6500K.
The *cold/warm primary axis* direction is shown set at a tangent to the black body locus at the D_{65} point, close to 6500K.
D_{65} is an industry standard artificial light source that does not lie on the black body locus.

Figure 3.
While 'colour temperature' remains a general working term it suffers from being an uneven scale of perceptual colour differences. Figure 3 shows how colour temperature increments are bunched together at the blue end of the scale — high values of colour temperature — while Mired values are visually much more evenly spaced and are therefore the chosen calibration increments for the *primary control.*
The Mired locus can be tracked by using a look up table (LUT) or a mathematical formulae. Such a formulae can be derived from the ellipse that fits the Mired locus very closely from 125 mired (8000K) to 450 mired (approx. 2200K), shown in Figure 3.

CLAIMS

1. The specification provides a simple means to adjust the hue balance of colour reproducing systems with the use of two operational controls only. One of them, the primary control, operates in a cold/warm direction, so arranged to follow the Planckian locus curve. The other control, the secondary control, operates in the green/magenta direction at D_{65} and along lines of correlated colour temperatures at other points on the Planckian locus. Operation of these controls provides continous adjustment to all phases of daylight and all types of artificial lighting.

2. The primary control in Claim 1 can be set to continously follow the Planckian locus.

3. The primary control in Claim 1 can be preset to a series of selectable fixed points on the Planckian locus.

4. The primary control in Claim 1 can be set to follow a straight line at a tangent to the Planckian locus at D_{65} as a compromise setting, *as illustrated in Figure 2.* While not tracking a wide range of the Planckian locus this is a useful compromise for white points close to D_{65} and may suffice for some applications.

5. The secondary control axis in Claim 1 is arranged to operate in a direction that crosses the primary control axis at D_{65} thereby allowing the daylight locus to be tracked and the yellow/green hue of discharge flourescent lighting to be corrected. Since the daylight locus is on the green side but very close to the Planckian locus the two may be considered to be together for practical reasons. The secondary control would be adjusted for very exacting work. *See Figure 2.*

6. The secondary control in Claim 1 could be programmed to operate along the lines of correlated colour temperature. *See Figure 1.*

7. Operation of the two controls in Claim 1 together allows any hue to be adjusted for effect or design requirements, beyond those that apply to normal lighting and white point adjustment.

8. Operation of the primary control in Claim 1 can be arranged to follow or track the Planckian locus by the use of electronic circuits controlled by a computer programme.The cold/warm direction at any given colour temperature is at a tangent to the Planckian locus at that colour temperature. *Figure 2 illustrates the cold/warm axis direction at the D_{65} point in the Planckian locus curve.*

9. The effect of operating the primary control as in Claim 1 and Claim 8 would be to alter the hue in a programmed cold/warm direction, thereby avoiding the colour naming and trial-and-error methods necessary to operate a control system requiring adjustment of three individual primary controls.

10. The primary control in Claim1 and Claim 8 can be arranged to follow or track the Planckian locus by using a look up table.

11. The primary control in Claim 1 and Claim 8 can be arranged to follow or track the Planckian locus by using a formulae derived from an elipse. *See Figure 3.*

12. It is intended that the visual spacing of the hue increments resulting from the operation of the primary control described in Claim 1, Claim2, Claim 3, Claim 8 and Claim 10 correspond to Mired intervals or multiples thereof. *See Figure 3.*

13. The primary and seconday controls in Claim 1 can be presented in the form of a key pad as illustrated in *Figure 4.*

14. The primary and seconday controls in Claim 1 can be presented in the form of slider or joystick controls as illustrated in *Figure 5.*

15. The primary and seconday controls in Claim 1 can be presented in the form of a Windows/Mac menu display, as illustrated in *Figure 6.*

16. The primary and seconday controls in Claim 1 can be presented in th form f keyboard arrow keys, asillustrated in *Figure 7.*

17. Operation of the primary and secondary controls outlined in Claim 1, by activating the control key pad in Claim 13; or by activating the screen menu buttons in Claim 15; or by activating th. keyboard keys in Claim 16; shall alter the screen hue by a just noticeable difference (JND) at a single activation. Continous activation will alter the screen hue by several JND's for a few seconds in a 'fine adjust mode'. Further uninterupted activation will speed up the hue change in a 'coarse adjust mode'.
The foregoing is facilitated by adopting the mired intervals outlined in Claim 12.

18. An operational routine for Claim 16 would be as folows.
A single key press would operate the hue correction one just noticeable difference (JND). Greater ammounts of correction can be added by operating either Ctrl+Arrow key or, Alt+Arrow key, to increase the increment to *n x* (JND).

Am ndm nts t th claims have be n filed as f llows

Claim 1.
The specification provides control of hue balance of colour reproducing systems by operating two manual controls. One of them, the *primary control*, operates in a cold/warm direction, so arranged to follow the shape of the black body locus. The other control, the *secondary control*, operates in a green/magenta direction and is aligned in the direction of correlated colour temperature lines. See Figures 1 and 2.

Operation of the secondary control offsets the *primary control* to follow either (a) the black body locus or (b) the daylight/artificial light side of the black body locus.

The *secondary control* operates in a direction across the *primary control* thereby allowing the *primary control* to be offset to the daylight locus. The secondary control also permits correction of the yellow/green hue of discharge fluorescent lighting as well as the hue of other types of gas discharge lighting.

Since the daylight locus is on the green side but very close to the black body locus the two may be considered to be the same shape for practical considerations.

Claim 2.
The *primary* and *secondary* operational controls claimed in Claim 1 simplify the adjustment of hue colour balance by reducing the number of controls from three to two and further by restricting the gamut of the *primary control* to a cold/warm effect.

Claim 3.
Combined operation of the *primary* and *secondary* controls claimed in Claim 1 provides continuous adjustment to all phases of daylight and all types of artificial lighting. Extended operation of both controls allows any hue to be adjusted for effect or design requirements, beyond those that apply to a normal 'white point' balance.

Claim 4.
The visual spacing of the hue increments resulting from the operation of the *primary control* described in Claims 1, 2 and 3, should follow the Mired interval scale.

Claim 5.
The *primary control* in Claims 1, 2, 3 and 4, can be arranged to track the black body locus by using a look up table (LUT).

Claim 6.
The *primary control* in Claims 1, 2, 3, 4 and 5 can be arranged to track the black body locus by using a formulae derived from a close fitting ellipse, as shown in Figure 3.

8

Patents Act 1977 **I miner's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9311691.1
Relevant Technical Fields (i) UK Cl (Ed.M) H4F FGB, FGC (ii) Int Cl (Ed.5) H04N 1/46, 9/64, 9/73	Search Examiner MISS S E WILLCOX
	Date of completion of Search 30 AUGUST 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI, INSPEC	Documents considered relevant following a search in respect of Claims :- 1

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
X	EP 0475320 A2 (YUNNAN TV FACTORY) see abstract	1

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